Science & Sports (2019) 34, 216—221

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Elsevier Masson France EM|consulte www.em-consulte.com

ORIGINAL ARTICLE

The effects of aerobic and resistance exercise on state anxiety and cognitive function

Effets de l'exercice aérobie et de l'exercice de résistance sur l'anxiété d'état et la fonction cognitive

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Received 11 September 2018; accepted 26 September 2018
Available online 17 April 2019

KEYWORDS
Physical activity;
Fitness;
Resistance training;
Anxiety;
Stress;
Cognitive function

Summary
Background. — There is a paucity of data directly comparing the effects of aerobic versus resistance exercise within a single cohort.
Objective. — The study aimed to investigate the effects of an acute bout of aerobic and resistance exercise on state anxiety and cognitive function.
Equipment and methods. — Participants completed three laboratory visits randomized between aerobic exercise (cycling at a self-selected intensity), resistance exercise (three sets; 10 repetitions; six exercises), and a control condition (seated rest). State anxiety and cognitive function were assessed before and after each condition.
Results. — Reductions in state anxiety that approached significance were seen immediately following aerobic exercise yet were non-significant in the resistance and control conditions. Cognitive function significantly improved following aerobic exercise yet this was not evident in the resistance or control conditions.
Conclusion. — Acute aerobic exercise at a self-selected intensity may be an effective way of reducing state anxiety and improving cognitive function, when compared to seated rest or resistance training.

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https://doi.org/10.1016/j.scispo.2018.09.004
0765-1597/

MOTS CLÉS
Activité physique ;
Forme physique ;
Entraînement en résistance ;
Anxiété ;
Stress ;
Fonction cognitive

Résumé
Contexte. — Il existe peu de données comparant directement les effets de l'exercice aérobie à celui de la résistance au sein d'une même cohorte.
Objectif. — L'étude visait à étudier les effets d'un exercice aigu aérobique et de résistance sur l'anxiété d'état et la fonction cognitive.
Matériel et méthodes. — Les participants ont effectué trois visites de laboratoire randomisées entre un exercice aérobie (cyclisme à une intensité auto-sélectionnée), un exercice de résistance (trois séries, 10 répétitions, six exercices) et une condition de contrôle (repos assis). L'anxiété d'état et la fonction cognitive ont été évaluées avant et après chaque condition.
Résultats. — Des réductions de l'anxiété d'état proche de la signification ont été observées immédiatement après l'exercice aérobique, mais elles n'étaient pas significatives dans les conditions de résistance et de contrôle. La fonction cognitive s'est considérablement améliorée après l'exercice aérobie, mais cela n'était pas évident dans les conditions de résistance ou de contrôle.
Conclusion. — L'exercice aérobie aigu à une intensité auto-choisie peut être un moyen efficace de réduire l'anxiété et d'améliorer la fonction cognitive, comparativement au repos assis ou à l'entraînement en résistance.

1. Introduction

Anxiety can be defined as an abnormal and overwhelming sense of apprehension and fear that results when the individual doubts his or her ability to cope with the situation that causes him or her stress [1]. Anxiety is one of the most prevalent mental disorders affecting more than 40 million or 18.1% of American adults, and is often accompanied by cognitive impairment, with specific deficits in short-term memory and reasoning [2,3]. One of the highest risk groups for anxiety and impairment to cognitive function are college students. It has been reported that college students reported frequently experiencing some form of anxiety on a daily basis [4]. Much of this anxiety can be attributed to the common academic pressures such as homework and tests, as well as the economic and social pressures of achieving the high marks associated with successful career options and acceptance to graduate level programs. If stress decreases cognitive abilities, and students report being stressed on a daily basis, this could be problematic since cognitive function plays a major role in academic performance [5]. Exercise could provide college students with a potential solution to alleviate symptoms of stress and consequently enhance cognitive function as exercise is considered to be easily accessible, affordable, and associated with minimal side effects.

While there is a plethora of data on the effects of exercise on preventing diseases such as cancer [6], Type 2 Diabetes [7], obesity, improving cardiovascular disease [8], and bone density, there is conflicting evidence on the relationship between exercise, anxiety reduction and cognitive function. Several reviews generally support the belief that acute exercise is associated with improved performance of cognitive tasks performed following the exercise session [9,10]. Previous studies indicate that stress impairs cognitive function, yet both aerobic exercise and resistance training may improve it and subsequently reduce stress. However, no study thus far has compared the effects of both aerobic and resistance exercise on anxiety and cognitive function within a single cohort. The aim of this study is to investigate the effects of an acute bout of self-selected aerobic exercise and an acute bout of resistance exercise on state anxiety and cognitive function.

2. Method

2.1. Participants

Thirty undergraduate college students ($n = 30$; 15 male, 15 female; $M_{age} = 21.2$ years) from a private university in the United States were recruited. Information concerning the study was distributed by word of mouth and interested students were scheduled for testing sessions via email. All participants signed an informed consent form prior to testing and the institution's review board provided ethical approval for the study.

2.2. Procedures

Testing consisted of three visits randomized between aerobic exercise, resistance exercise, and control conditions. During the first visit, participants completed questionnaires measuring trait level anxiety and state-level anxiety and completed two computer-based cognitive tests. Dependent upon which condition they were in, participants were then asked to complete either one of two exercise conditions or a control protocol. In the control condition, participants were asked to rest quietly in a seated position for 35 minutes, during which they were allowed access to a computer for purposes of entertainment, homework, or social media. However, all control participants chose to use social media. After 35 minutes of seated rest, state-level anxiety and cognitive tasks were assessed. The aerobic exercise condition involved 35 minutes of cycling at a self-selected pace and resistance. The resistance exercise condition consisted of

three sets of ten repetitions of six bilateral exercises: bench press, leg press, shoulder press, bicep curl, wide-grip lateral pulldown, and leg extension, each with 90 seconds of rest between them. Participants were instructed to choose a weight that they could lift comfortably for ten repetitions. After both exercise conditions, state-level anxiety and cognitive tasks were assessed.

2.3. Measures

2.3.1. State anxiety inventory

State anxiety was assessed using the 10-item State Anxiety Inventory [11] which consists of 10 statements regarding how a participant is feeling at that given moment in time. This inventory uses a 4-point Likert scale ranging from ''not at all'' to ''very much so.'' The SAI is measure of anxiety that has been shown to be valid and reliable [12,13].

2.3.2. Trait anxiety inventory

Individual trait anxiety levels were determined using the Trait Anxiety Inventory 14. The TAI consists of 20 items that assess how that person feels in general, on average, or all of the time. Participants choose the response that best reflects how they feel. Based on norms for college-aged women and men, low-trait anxiety is reflected by scores < 28 for females and < 27 for males; high-trait anxiety is reflected by TAI scores > 40 for females and > 40 for males [14].

2.3.3. N-back task

To assess working memory, an online variant of the N-back memory task was used. In this version of the test, participants click on a ''hit'' box when the program repeats a picture that was viewed two items ago. Upon completion, number of responses, % correct responses, average response time, and combined time are generated. For the purposes of this study, % correct was utilized as the dependent variable in this task, as it contains the variance associated with number of responses, and the Stroop test is a better measure of processing speed.

2.3.4. Stroop task

The Stroop Task is used to assess information processing speed, executive abilities, selective attention, and ability to inhibit habitual responses [15]. An online variant of this task was used for the purposes of this study. Participants view color names displayed in consonant/dissonant colors of ink and are instructed to press the first letter of the name of the color that is shown (in this scenario, ''b'' for blue). After 20 trials, an output of the participant's fastest response, slowest response, average response time, deviation time, % correct, and combined response time is generated for both the normal (''yellow'' displayed in yellow font) and interference (''yellow'' displayed in blue font) conditions. Average response time was retained as the dependent variable for this task.

2.4. Statistical analysis and power calculation

Data were checked over prior to analysis using descriptive, histograms overlain with normal distribution curves, and Anderson-Darling normality tests. Three dependent variables were examined: anxiety, and cognitive function both in terms of processing speed (the Stroop test) and memory (the N-Back). A repeated measures ANCOVA was used to assess changes in state-level anxiety, holding trait-level anxiety constant as a covariate. Paired-samples t-tests were used to examine differences in cognitive function between control, aerobic and resistance exercise conditions. All analyses were conducted using SPSS version 20 for Mac (SPSS, Inc, Chicago, IL) with α set at the 0.05 level. Our power calculation estimated that a mean difference Vo_{2max} between groups would be detectable with 0.75% power, a 0.5 effect size, at a significance 0.05, in 30 pairs of participants.

3. Results

In order to assess changes in state anxiety across the three conditions, a repeated measures ANCOVA was conducted, holding trait anxiety constant. No significant differences were found between pre and post measurements of state-level anxiety in the control condition ($F(1,28) = 1.14$, $P = 0.29$; $\eta^2 = 0.04$) or the resistance exercise condition ($F(1,28) = 1.23$, $P = 0.28$; $\eta^2 = 0.04$). While the aerobic condition had a similar outcome, ($F(1,28) = 3.86$, $P = 0.06$; $\eta^2 = 0.12$), this difference approached significance and trended in the hypothesized direction. Effect size η^2 for this difference may also be classified as close to large using Cohen's criteria (0.2 = small, 0.5 = medium; 0.7 = large), whereas it is ''small'' in the cases of both the control and resistance groups (Fig. 1).

In order to assess changes in attention and inhibition within the three conditions, paired samples t-tests were conducted on average speed (in seconds) on the Stroop Task (Fig. 2). There were no significant differences in Stroop Task performance before and after the control condition ($t(29) = -0.39$, $P = 0.74$; $d = 0.06$). No significant differences were found in Stroop Task performance before and after the resistance ($t(29) = -1.45$, $P = 0.16$; $d = 0.26$) or aerobic conditions ($t(28) = 1.51$, $P = 0.14$; $d = 0.28$). However, only the aerobic condition showed an increase in processing speed; participants in both control and resistance conditions took longer in the Stroop task post-assessment, yet this was not apparent for participants in the aerobic exercise condition.

In order to assess changes within the three conditions, paired sample t-tests were run using % correct on the N-Back Task (Fig. 3). Participants in the aerobic condition performed significantly better on the N-Back task after the intervention, ($t(28) = 2.62$, $P = 0.01$; $d = 0.49$). No significant differences were found in N-back Task performance before and after the control condition ($t(29) = 1.49$, $P = 0.15$; $d = 0.27$) or the resistance condition ($t(29) = 1.58$, $P = 0.13$; $d = 0.28$).

4. Discussion

The purpose of this study was to investigate and compare the acute effects of aerobic and resistance training on state anxiety and cognitive function (Table 1). To the authors' knowledge, this is the first study to directly compare the effects of aerobic and resistance exercise in regards to reducing state anxiety and improving cognitive function

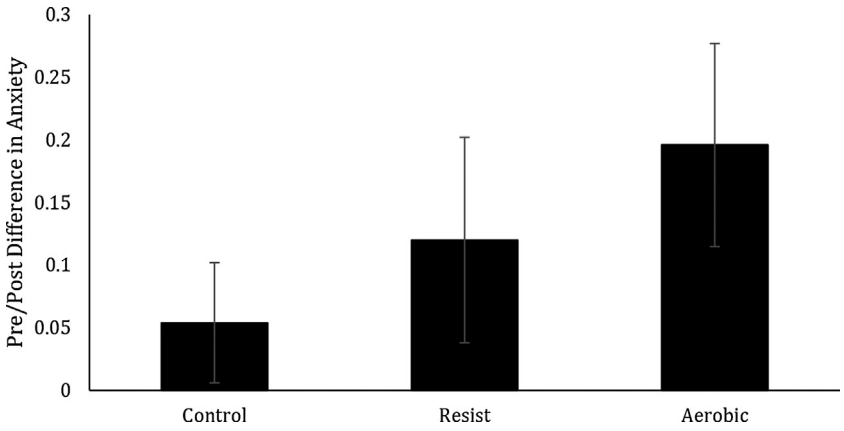

Figure 1 Comparison of pre/post differences in state anxiety across conditions.

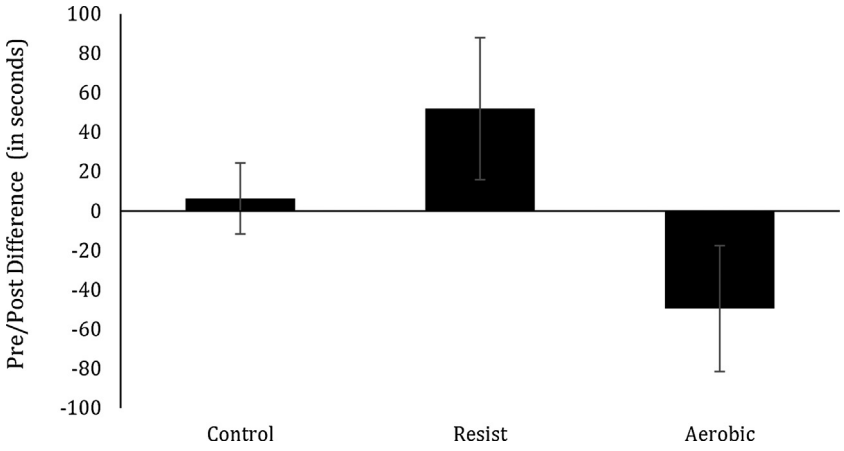

Figure 2 Comparison of pre/post differences in Stroop reaction time across conditions.

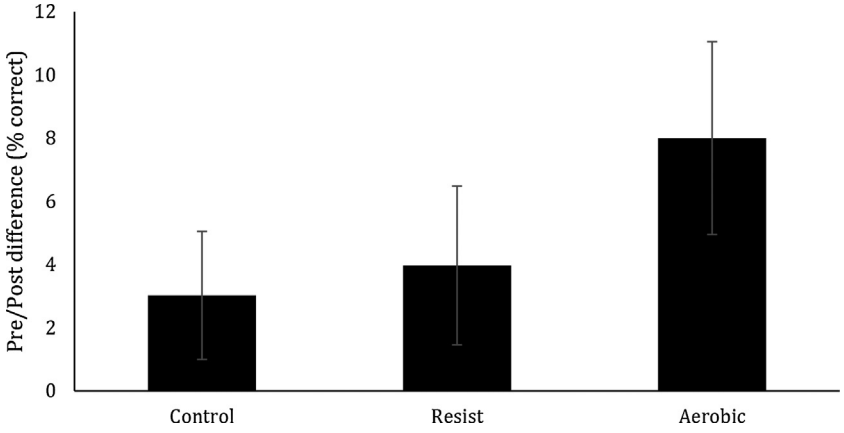

Figure 3 Comparison of pre/post differences in N-Back memory across conditions.

within the same cohort. While some of the outcomes were statistically non-significant, the key findings of this study indicate that acute aerobic exercise may be an effective means of reducing state anxiety and improving cognitive function. Furthermore, the results suggest that acute resistance exercise may not be an effective means of reducing state anxiety and improving cognitive function. This is in agreement with evidence in the current literature that aerobic exercise reduces state anxiety [16]. Previous studies investigating the effect of resistance exercise on reducing state anxiety have yielded mixed findings. For example, Focht (2002) found reductions in state anxiety regardless of intensity; however, their study assessed anxiety at multiple time points up to 120 minutes after the exercise condition, whereas the current study only tested anxiety immediately after resistance exercise [17]. A possible explanation as

Table 1 Anthropometric and demographic characteristics of participants.

Variable	M	(SD)
Age (years)	21.17	2.09
Height (meters)	1.72	0.09
Weight (kilograms)	70.7	9.28
BMI (kg/m2)	23.62	2.37

to why the resistance exercise condition did not elicit the significant reduction in state anxiety sometimes reported may be engagement of the autonomic nervous system. As resistance exercise activates the parasympathetic nervous system, it may engender transient physiological responses that contribute to a false representation of anxiety due to the wording of the state anxiety inventory. For example, the prompts ''I am tense'' and ''I am jittery'' might lead participants to score higher on the SAI due to misattribution of arousal—their feelings of being ''tense'' and ''jittery'' may be directly attributable to parasympathetic activation and last for only a short time. To avoid this scenario, future experiments could retest anxiety after both a period of rest as well as immediately post-exercise.

Aerobic exercise did not significantly improve performance on the Stroop Color Reading Interference Task, which measures executive processing and selective inhibition. However, performance following the aerobic exercise condition trended in the predicted direction while the other two conditions actually showed decrements in performance. This finding of improvement following aerobic exercise, while not significant, is in agreement with previous research which showed improvements in selective inhibition followed acute aerobic exercise [18].

Significant improvements were seen in the N-back Working Memory Task following acute aerobic exercise, which directly contradicts the findings of Coles and Tomporowski (2007), who did not report significant differences between their control and exercise conditions in short term memory [19]. However, their sample size ($n = 19$) was relatively small and their protocol involved 40 minutes of cycling at 90% ventilatory threshold while the aerobic exercise protocol of the current study involved 35 minutes of self-selected intensity cycling. Improvements following resistance exercise were not found in working memory performance. A study conducted by Pontifex, Hillman, Fernhall, and Thompson (2009) found an improvement following aerobic exercise that was not apparent following resistance exercise which is in agreement with the findings of the current study [20].

In conclusion, the results of this study indicate that acute aerobic exercise can effectively reduce state anxiety and improve cognitive function, when compared to rest and resistance exercise. These findings may provide a relatively safe and low-cost intervention to assist college students in managing their stress and improving the cognitive processes linked to academic performance.

Ethical approval

The Institutional Review Board of the California Lutheran University approved this study, and all procedures were performed in accordance with standards outlined in the Helsinki Declaration.

Authors contributions

Drs. Kelly and Wagerman had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analyses.

Study concept and design: Hill; Drs. Kelly and Wagerman.

Acquisition of data: Hill, Flores.

Analysis and interpretation of data: Drs. Wagerman, Knowles and Kelly.

Drafting of the manuscript: All authors contributed to the drafting of the manuscript.

Critical revision of the manuscript for important intellectual content: Drs. Wagerman, Knowles and Kelly.

Statistical analysis: Wagerman, Kelly.

Obtaining funding: N/A.

Administrative, technical, or material support: Hill.

Study supervision: Drs. Kelly and Wagerman.

Support: None reported.

Financial Disclosers: None reported.

Data Sharing: There is no additional data available.

Disclosure of interest

The authors declare that they have no competing interest.

Acknowledgements

We would like to thank all the participants for their help with this study.

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